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Pedotransfer functions estimating near-Saturated and Saturated Hydraulic Conductivities

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Introduction

Leaching of pesticides and phosphorus through fine-textured, structured soils is mainly controlled by colloid-facilitated transport in the macropores of the soil. Estimates of hydraulic conductivities in the near-saturated and saturated range using pedotransfer functions (PTFs) can be useful in predicting the potential of water transport in the macropores. The initiation of water transport in the macropores is controlled by two factors: The hydraulic conductivity in the soil matrix and the presence or absence of macropores. Soils with macropores and with a low near-saturated hydraulic conductivity are believed to show the highest degree of preferential transport.

Objectives

This study aims at developing parametric PTFs to predict the near-saturated hydraulic conductivity (here defined as the conductivity at a soil water potential of -1 kPa, $k(-1)$) and the saturated hydraulic conductivity (K_s) using simple soil parameters as predictors.

Materials and Methods

This data set was based on hydraulic measurements on large undisturbed soil columns (6280 cm^3 , = 20 cm) covering a variety of different Danish soil types (Fig. 1). The soil columns were sampled from excavated soil profiles from soil horizons of hydrological interest. Each soil profile was texturally, geochemically, and pedologically described.

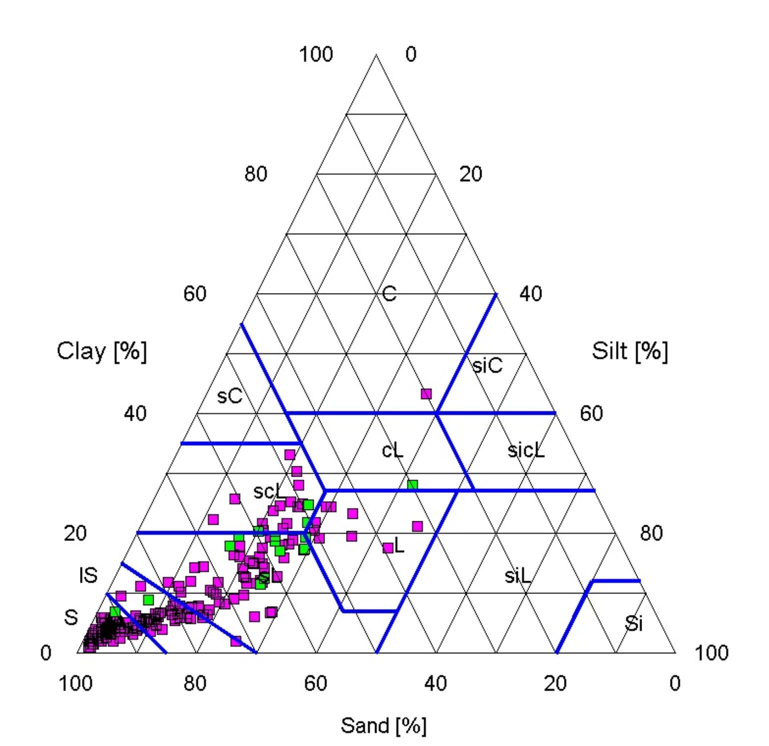

Fig. 1. Textural distribution of the investigated soils (USDA classifcation). Pink squares: both $k(h)$ and K_s measured, Green squares: K_s measured only.

Laboratory

In the laboratory, the unsaturated hydraulic conductivity ($k(h)$) was measured on a total of 472 columns using a drip infiltrometer (van den Elsen et al., 1999). K_s was measured on a total of 792 columns using the constant head method (Klute and Dirksen, 1986).

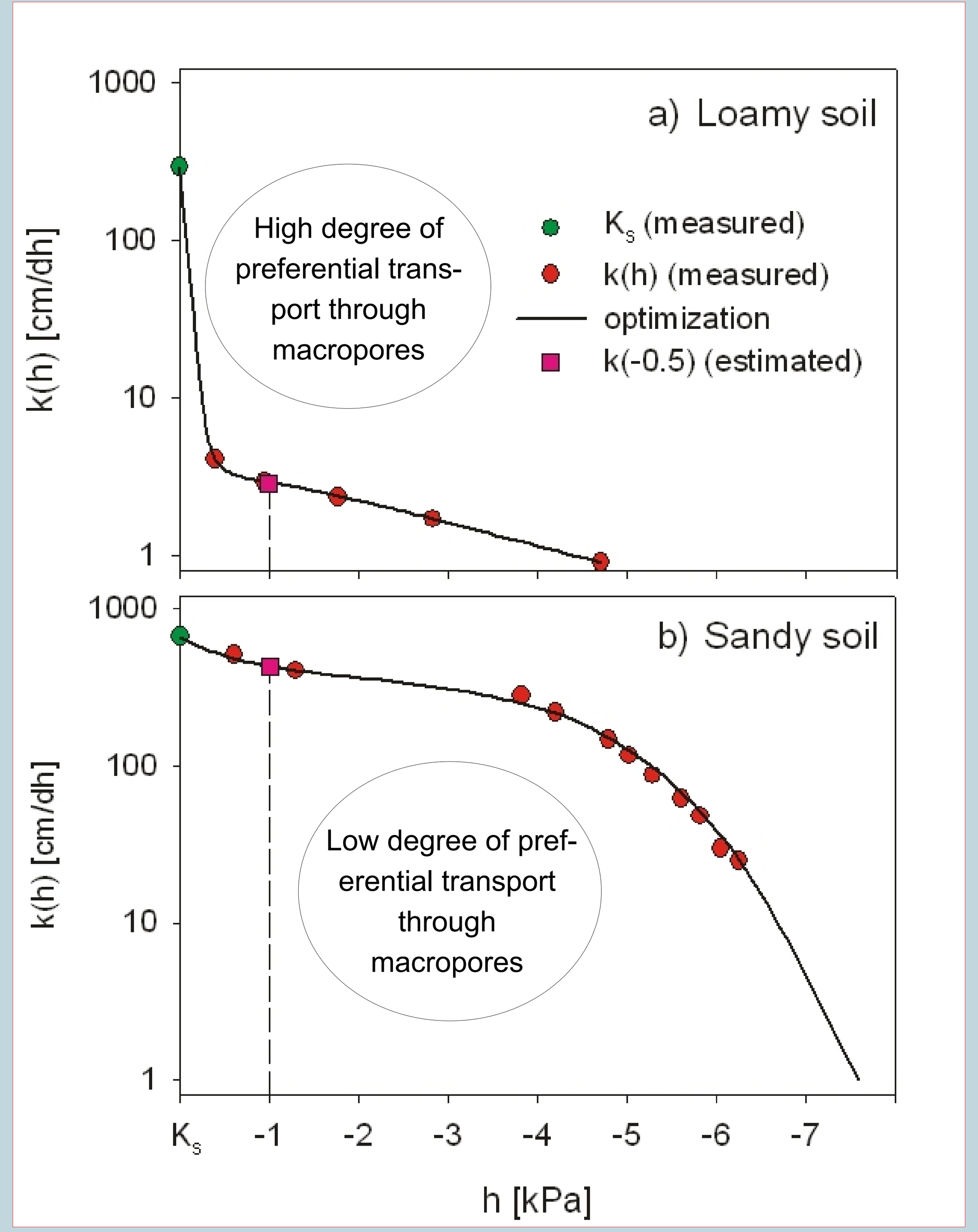

Fig. 2. Examples of measured K_s and $k(h)$ on a) a loamy soil and b) a clay soil. Also shown are fitted data and estimated k(-1).

Data optimization

The hydraulic data set was optimized using a modified version of the van Genuchten-Mualem model combined with an empirical scaling function to account for the rapid increase in conductivity near saturation (Børgesen et al., 2006). From this function $k(-1)$ was estimated (Fig. 2).

PTF development

The developed PTFs were based on neural networks and the Bootstrap method using different sets of predictors. Sixty replica data sets were generated, each of which was used to calibrate the neural network model. The different predictors used in the neural network are summarized in Table 1.

Table 1. Predictors used in the neural network.

Predictor	Description
7-TXT	Seven texture classes†
4-TXT	Four texture classes (Danish classification system)‡
3-TXT	Three texture classes (USDA soil classes)§
SOM	Soil organic matter
HOR	Horizon
BD	Bulk density
LSP	Soil pores larger than 0.3 mm¶
SG	Soil grade (weak to strong)

† <2 m, 2-20 m, 20-63 m, 63-125 m, 125-200 m, 200-500 m, 500-2000 m
‡ <2 m, 2-20 m, 20-200 m, 200-2000 m
§ <2 m, 2-50 m, 50-2000 m
¶ based on soil water charecteristic measurements on 100 cm^3 soil samples

Table 2. Root mean square errors (RMSE) of the differents sets of PTFs using different sets of predictors.

Predictors†	RMSE K_s	RMSE k(-1)
7-TXT	0.85	0.64
7-TXT,SOM,	0.82	0.62
7-TXT,SOM,HOR,BD	0.76	0.58
7-TXT,SOM,HOR,BD,LSP,SG	0.78	0.54
4-TXT	0.89	0.67
4-TXT,SOM,	0.87	0.66
4-TXT,SOM,HOR,BD	0.83	0.61
4-TXT,SOM,HOR,BD,LSP,SG	0.82	0.56
3-TXT	0.92	0.68
3-TXT,SOM,	0.86	0.67
3-TXT,SOM,HOR,BD	0.85	0.63
3-TXT,SOM,HOR,BD,LSP,SG	0.85	0.62

† See describtion in Table 1

Results and Discussion

The result showed that the neural network was able to develop reasonably accurate predictions of $k(-1)$ using PTFs whereas K_s was less accurately predicted (Table 2, Fig. 3). When decreasing the number of texture predictors, the uncertainty of the prediction of K_s and $k(-1)$ increased. This increase was most pronounced for the K_s measurement.

The results from the neural network (the PTF using 4-TXT, SOM, HOR, BD) together with a newly developed raster-based soil property map of Denmark (Greve et al., 2006) were used to construct a map showing the distribution of logK_s and log$k(-1)$ in the A horizon (Fig. 4a & b).

The difference between logK_s and log$k(-1)$ (Fig. 4c) combined with a low value of log$k(-1)$ (Fig. 4b) might be an indication of soils showing a high degree of preferential transport through soil macrpores.

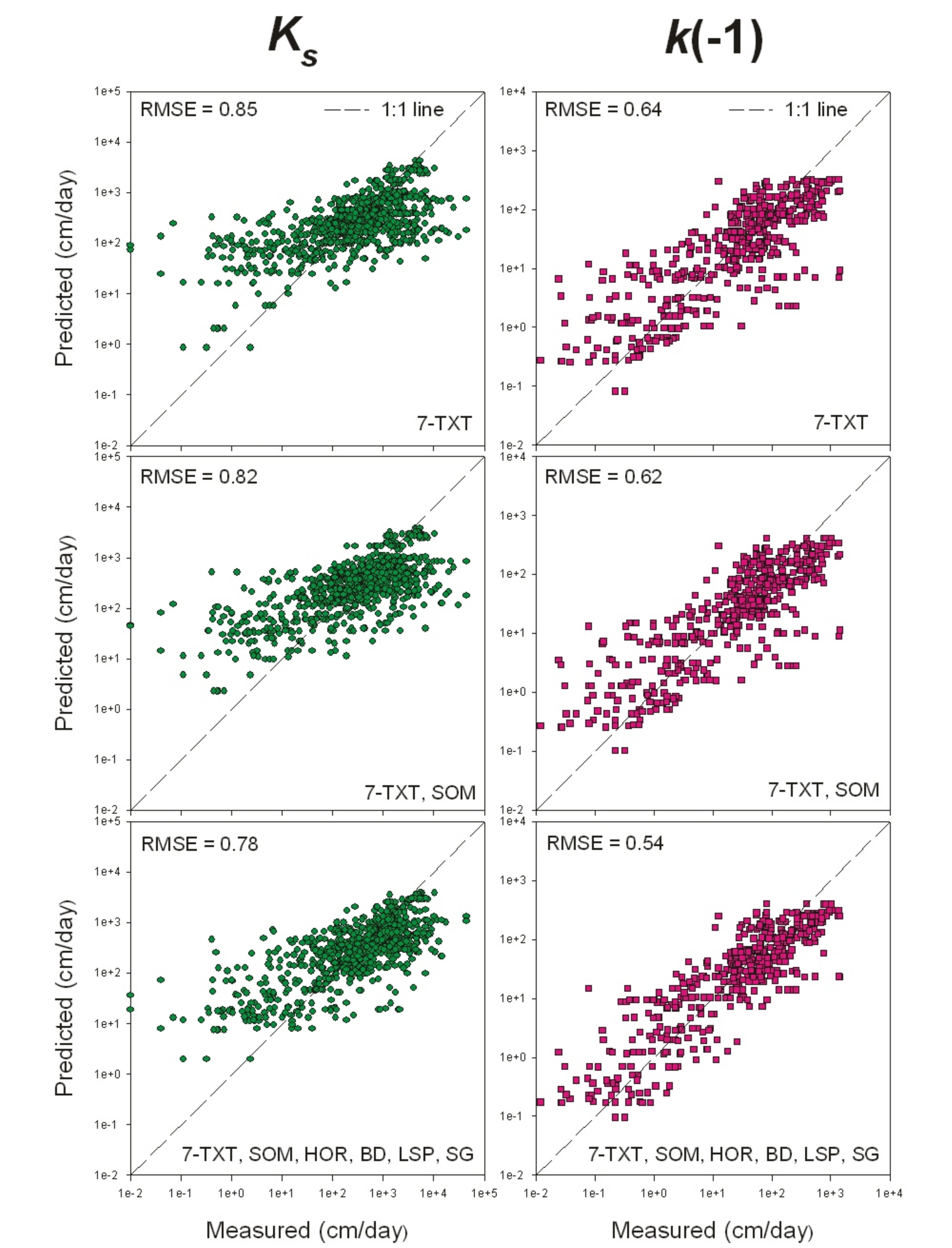

Fig. 3. Predicted and measured K_s and $k(-1)$ using PTFs with seven texture classes (for explanation see Table 1).

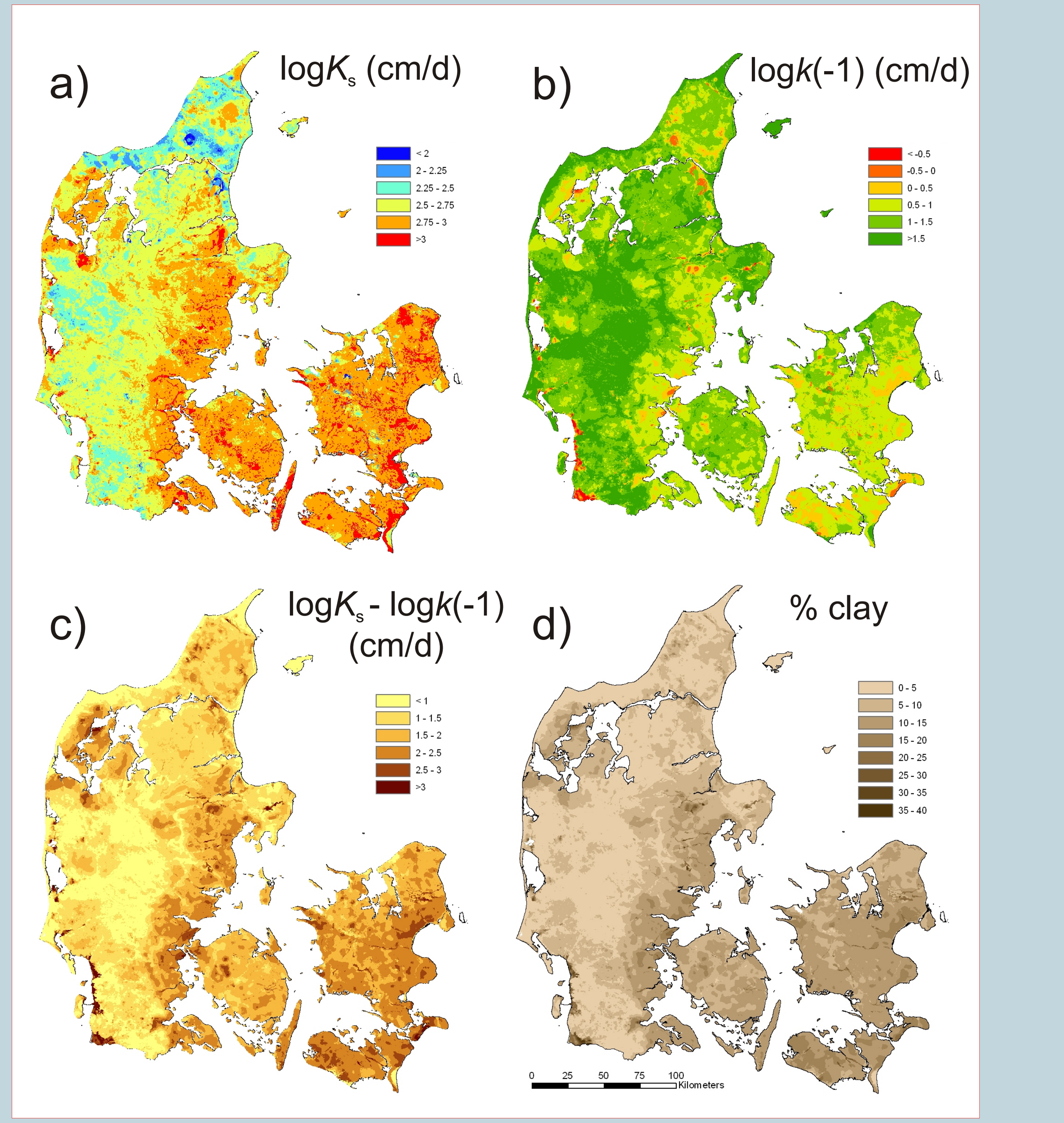

Fig. 4. Maps of Denmark showing predicted a) logK_s, b) log$k(-1)$, and c) logK_s - log$k(-1)$ in the A horizon. PTF used is 4-TXT, SOM, BD, and HOR (see Table 1). Also shown is d) distribution of clay. Resolution of maps is 250 m.

Conclusion

The results open up for the possibility of generation maps of soil hydraulic parameters, which can be used to identify areas at high risk of water transport in macropores.

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